



## **The effect on wave nonlinearity on monopile and tower. Fatigue loads in misaligned wind/sea conditions**

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# The effect on wave nonlinearity on monopile and tower. Fatigue loads in misaligned wind/sea conditions

Danish Wind Power Research Conference  
May 27<sup>th</sup> – 28<sup>th</sup> , 2013

Signe Schlører

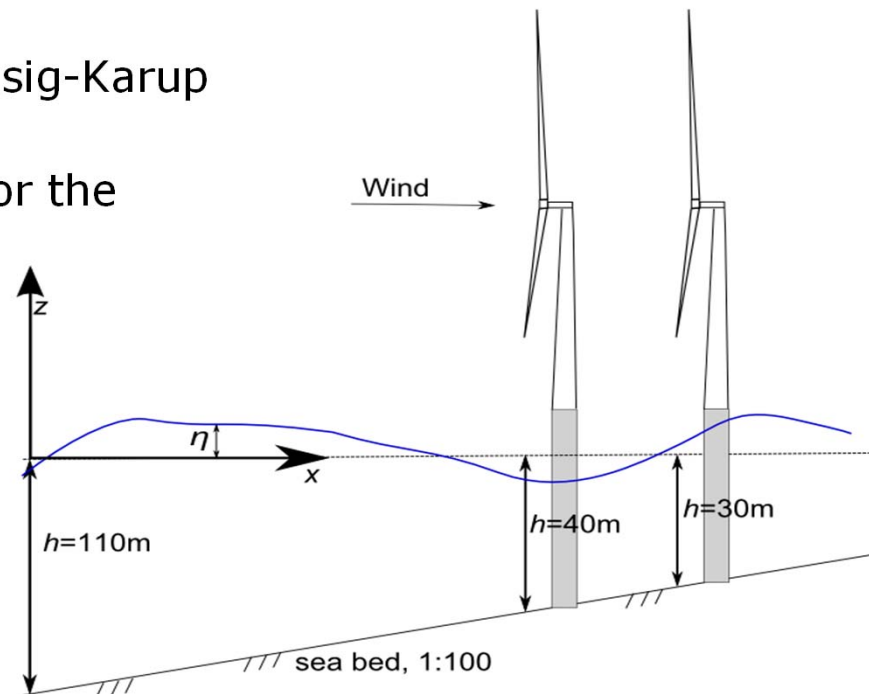
Henrik Bredmose

Statkraft Ocean Energy  
Research Program



# The models

- Fully nonlinear wave model [Engsig-Karup et.al. (2009)]
  - Solve the Laplace equation for the velocity potential
- Aeroelastic code
  - Flex5 [Øye, S. (1996)]
  - Nrel 5MW wind turbine on a monopile

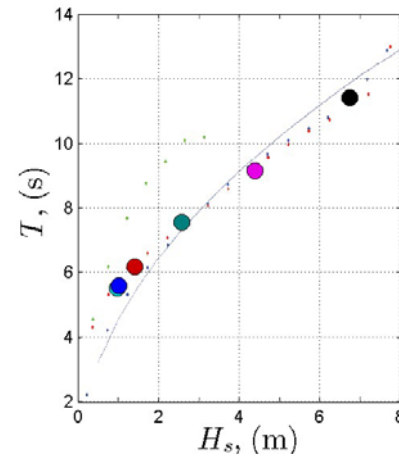
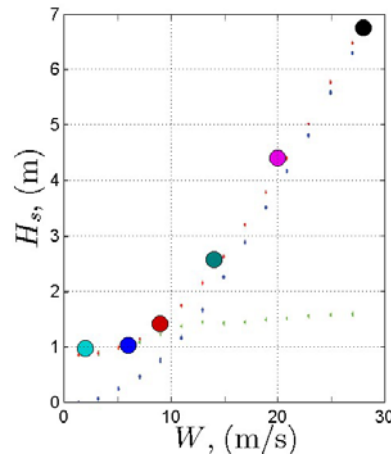
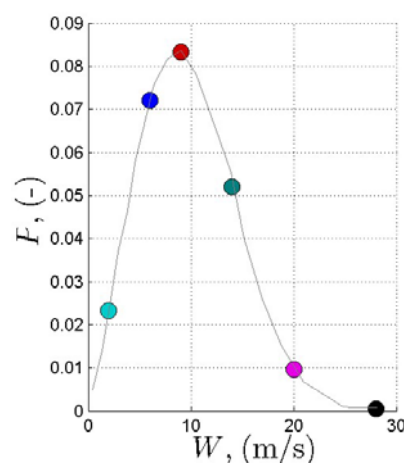


Possible to compare fully nonlinear and linear irregular waves

# Metoccean data

## From the North Sea

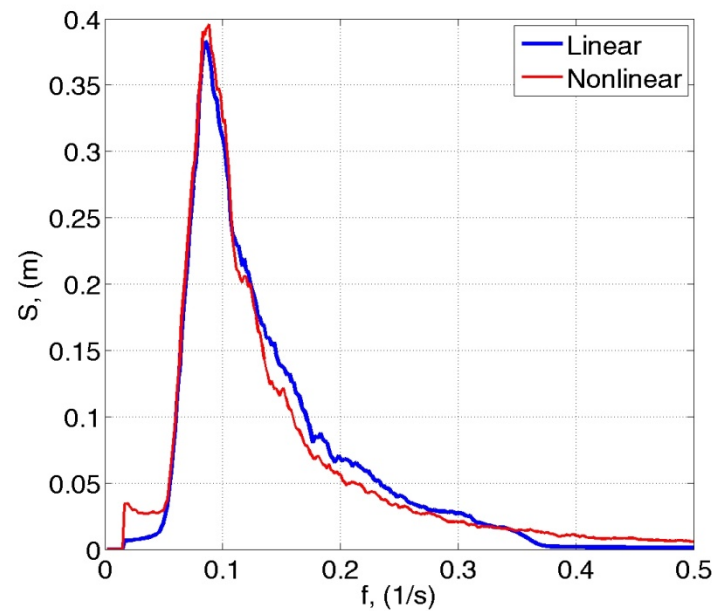
$V$ (m/s)	$H_s$ (m)	$T_p$ (s)	$P_{rel,j}$	$P_{rel,i,j} \cdot 10^2$						
				$0^\circ$	$30^\circ$	$60^\circ$	$90^\circ$	$120^\circ$	$150^\circ$	$180^\circ$
2	0.99	5.50	0.1	1.0	2.2	1.8	1.5	1.2	1.2	0.59
6	0.99	5.50	0.3	6.6	10	5.7	3.2	2.0	1.7	0.74
9	1.41	6.17	0.35	11	14.2	5.2	2.0	1.1	0.67	0.29
14	2.57	7.56	0.22	9.1	9.6	1.9	0.53	0.22	0.14	0.11
20	4.40	9.16	0.04	2.0	1.7	0.19	0.013	0.015	0.010	0.0
28	6.75	11.41	0.002	0.12	0.076	0.007	0.0	0.002	0.0	0.0



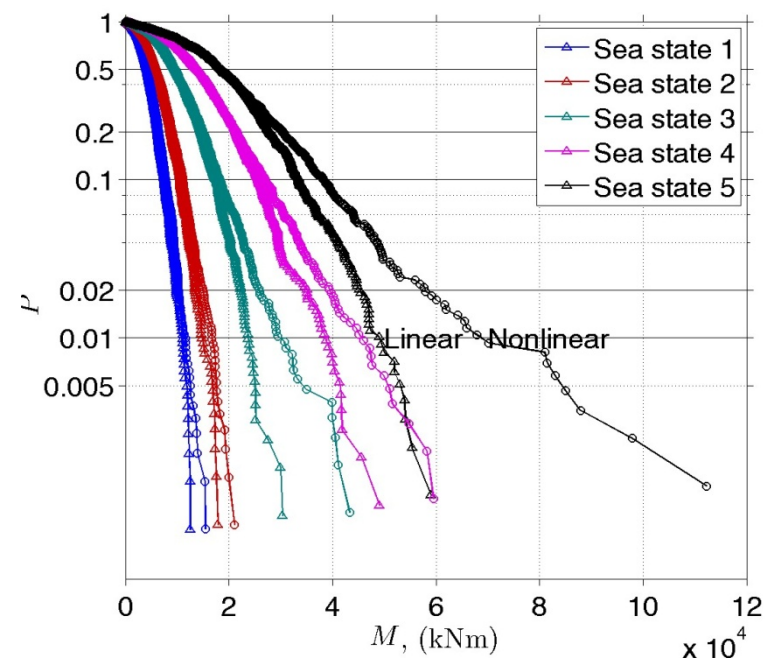
# Linear and nonlinear wave realizations

## Spectrum and overturning moment

$h=30$  m,  $H_s=6.75$ m,  $T_p=11.41$ s



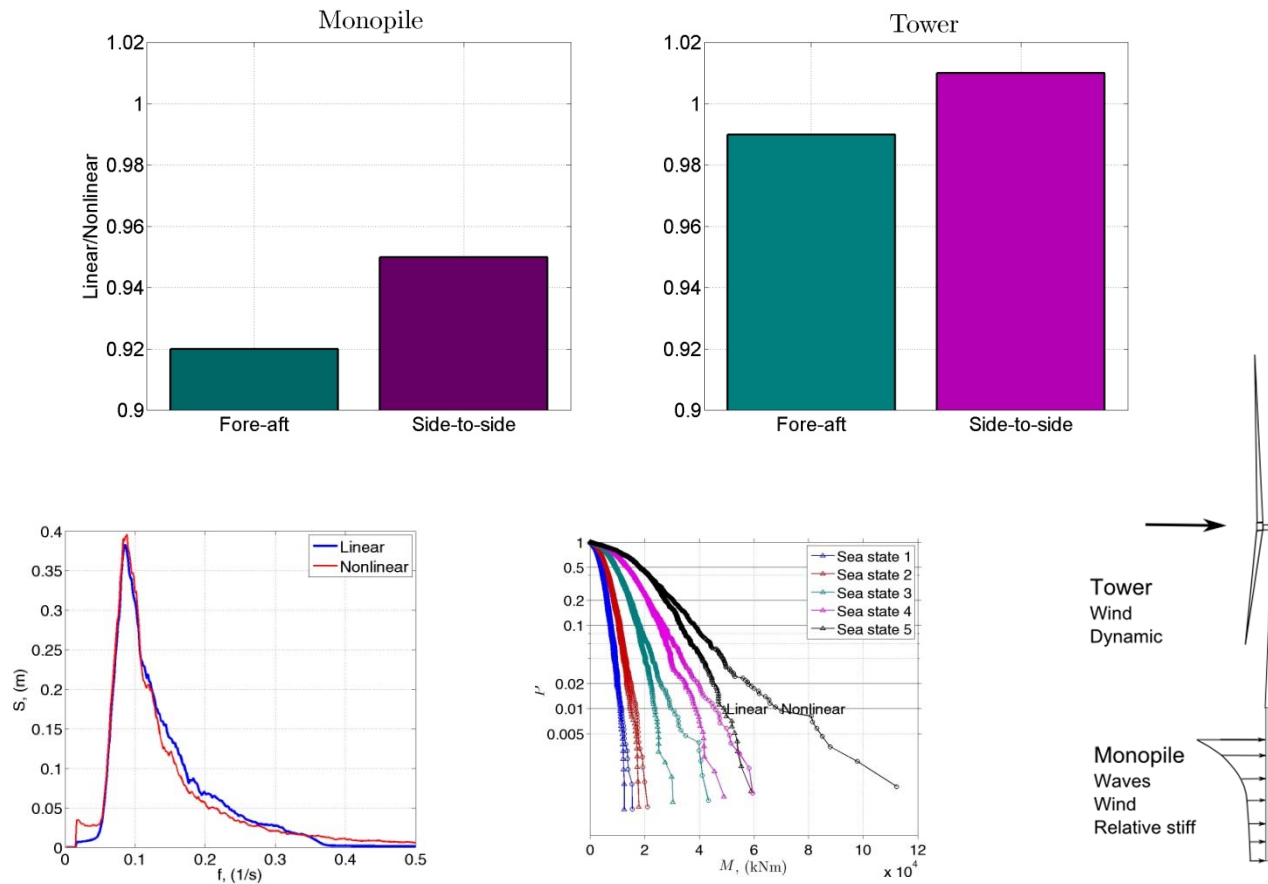
$h=30$  m



# Accumulated fatigue damage

Overturning moment,  $m=5$ ,  $h=40\text{m}$

Misalignment wind and waves



# Accumulated fatigue damage

Effect of water depth

Alignment wind and waves

